PATENT
Atty. Dkt. No. THOR/0010

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Stephen G. Porter et al	§	
	§	Group Art Unit: Unknown
Serial No.: 10/028,940	§	
Filed: December 21, 2001	§	Examiner: Unknown
Confirmation No.: unknown	§	
For: Use of Distorting Optics in Imaging Systems	§	

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

CERTIFICATE OF MAILING
37 CFR 1.8
I hereby certify that this correspondence is being deposited on the date below with the United States Postal Service as First Class Mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231.

20 Feb 02 — William B. Patterson
Date — Signature

CLAIM TO PRIORITY

Applicants reaffirm the claim for the benefit of filing date of the following foreign patent application referred to in Applicants' Declaration:

Great Britain Application Serial Number 0031572.1 filed December 22, 2000.

A copy of the application certified by the Great Britain Patent Office is enclosed.

Respectfully submitted,

Date: 20 Feb 2002

William B Patterson

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I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation and Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein together with the Statement of inventorship and of right to grant of a Patent (Form 7/77), which was subsequently filed.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

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Signed R. Mahoney

Dated 11 January 2002

CERTIFIED COPY OF PRIORITY DOCUMENT

0031572.1

Patents Form 1/77

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28DEC00 E594105-13 D00180
P01/7700 0.00-0031572.1

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22 DEC 2000
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Request for grant of a patent

22 DEC 2000

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1.	Your reference	EAD
2.	Patent application number *(The Patent Office will fill in this part)*	**0031572.1**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	INFRARED INTEGRATED SYSTEMS LIMITED TOWCESTER MILL, TOWCESTER, NORTHANTS NN12 6AD
	Patents ADP number *(if you know it)*	07473143001
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	Use of Distorting Optics in Imaging Systems
5.	Name of your agent *(if you have one)*	A A THORNTON & CO
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	235 HIGH HOLBORN LONDON WC1V 7LE
	Patents ADP number *(if you know it)*	0000075001 ✓

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))*	YES

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	6
Claim *(s)*	2
Abstract	1
Drawing *(s)*	16+10

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	1
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature AAThornton & Co. Date

A. A. Thornton & Co. 22.12.00

12. Name and daytime telephone number of person to contact in the United Kingdom

ELIZABETH ANN DAWSON 020 7405 4044

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Patents Form 7/77

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7/77

Statement of inventorship and of right to grant of a patent

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1.	Your reference	EAD
2.	Patent application number *(if you know it)*	0031572.1
3.	Full name of the or of each applicant	INFRARED INTEGRATED SYSTEMS LIMITED
4.	Title of the invention	Use of Distorting Optics in Imaging Systems
5.	State how the applicant*(s)* derived the right from the inventor*(s)* to be granted a patent	by virtue of employment
6.	How many, if any, additional Patents Forms 7/77 are attached to this form? *(see note (c))*	1
7.		I/We believe that the person*(s)* named over the page *(and on any extra copies of this form)* is/are the inventor*(s)* of the invention which the above patent application relates to. Signature AA Thornton & Co. Date A A THORNTON & CO 29.01.01
8.	Name and daytime telephone number of person to contact in the United Kingdom	Elizabeth A. DAWSON 020 7405 4044

Notes

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Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

Stephen George PORTER
15 Hicks Road
Towcester
Northants NN12 6EJ

Patents ADP number *(if you know it)*: 03987245002

Patents ADP number *(if you know it)*:

Reminder

Have you signed the form?

Patents ADP number *(if you know it)*:

Use of Distorting Optics in Imaging Systems

The present invention relates to an optical imaging system for forming an image of a field of view in an object plane onto an image plane.

In conventional imaging optics, as illustrated by way of example in Figure 1, a lens or mirror 1 is used to focus light rays 2 from an object plane 3, onto an image plane 4 and steps are generally taken to minimise optical distortions so as to produce a linear (i.e. proportional) relationship between areas of the object plane and areas of the image plane.

It is sometimes desirable to form an image of an area of ground (the object plane) on an image plane positioned above the ground at an oblique angle to the ground. An example of such an arrangement is shown in Figure 2 in which the image plane is designated by reference numeral 4 and the ground by reference numeral 6. The image plane might include a physical object such as a detector array mounted on a wall 5. An example of such an arrangement is a passive infrared intruder detector mounted on a wall. It is clear from an examination of Figure 2 that certain elements of the detector array are viewing only a small area of ground whilst other elements are viewing very large areas of ground. In certain applications it would be advantageous to provide a more uniform correspondence between areas of the object plane and areas of the image plane.

The problem is illustrated more clearly in Figure 3. Using the configuration of Figure 2, if a two dimensional array of 16 x 16 detector elements is used at the image plane, then the points 7 on the ground or object plane which are imaged onto the centres of the elements form an unevenly spaced array of points as illustrated in Figure 3. (In Figure 3 different symbols represent different rows of elements.) It is common practice to mount an intruder detector in a corner between two walls 8 and 9 and the requirement is to cover the area bounded by these walls as evenly as possible. Figure 3 shows that the points closest to the detector array are closer together and therefore they represent smaller areas than the points further away from the detector array.

Here there is still a linear relationship between areas of the object plane an areas of the image plane, but the relative sizes of object and image areas also depend on the distance between the object and the image which varies if the object and image planes are not parallel.

This problem cannot be solved adequately with conventional optics. For example, Figure 4 shows that the placing of a plane mirror 10 between the object plane and the image plane does not improve the situation.

The present invention provides an optical system for forming an image of a field of view in an object plane onto an image plane which is not parallel to the object plane in which a designated area of the object plane is mapped onto the image plane by means of a distorting optical element which imposes a non linear relationship between areas of the object plane and areas of the image plane. For applications such as the example described above, it is desirable that the optical distorting element at least partially compensates for the foreshortening of the image caused by the inclination of the object plane to the image plane.

The invention has been developed for use with an infrared detector array. For such an application the image need not be visible and therefore the distortion is not disadvantageous. It should be noted that the distorting element does not disrupt the positional relationship between areas of the object and image planes and therefore it is still possible to derive position information from the image without the need for additional signal processing.

For certain applications, such as that illustrated in Figure 2, the optical distorting element may be shaped so as to broaden the field of view in the x direction (Figure 3) whilst in the y direction the field of view is compressed for large values of y but expanded for small values of y. This would ensure better coverage of an area between two walls at right angles to each other.

Preferably the optical distorting element causes a more uniform

correspondence between areas of the object plane and areas of the image plane than would be present without the optical distorting element. The distorting element may be a reflective surface or a refractive element. The system may include a lens for focussing the image onto the image plane. As will be clear from the foregoing, in a preferred embodiment of the invention, an array of detector elements, such as infrared detector elements, is positioned at the image plane. The object plane may be an area of floor or ground and the image plane may be at an acute angle to the object plane.

An embodiment of the invention will now be described by way of example and with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram showing the relationship between areas of an object and areas of an image produced by a standard lens 1;

Figure 2 illustrates the foreshortening of the image, which is caused when the image plane is at an angle to the object plane;

Figure 2A is an enlarged view of the circled area of Figure 2:

Figure 3 illustrates the relationship between the points on the ground plane that are imaged onto the centres of the elements in a detector array in the example shown in Figure 2;

Figure 4 shows an arrangement similar to Figure 2 with the addition of a plane mirror;

Figure 4A is an enlarged view of the circled area of Figure4:

Figure 5 is a diagram similar to Figure 4 in which an optical distorting element is substituted for the plane mirror;

Figure 5A is an enlarged view of the circled area of Figure 5:

Figure 6 is a diagram corresponding to Figure 3 illustrating the effect of using the optical distorting element; and

Figure 7 is a perspective view of an optical distorting element used to produce the results shown in Figure 6.

Figure 8 shows various views of an alternative distorting element for

use with an optical system viewing the approach to a doorway:

Figure 9 is a schematic diagram showing a second example of a system according to the invention viewing the approach to a doorway;

Figure 9A is an enlarged view of the circled area of Figure 9: and

Figure 10 shows the field of view of the system of figure 9;

Figure 11 is a diagram similar to Figure 3 for the arrangement shown in Figure 9;and

Figure 12 is a diagram similar to Figure 6 for the arrangement of Figure 9 showing the effect of using the reflector illustrated in Figure 8.

In the example illustrated in Figure 5, the plane mirror 10 of Figure 4 has been replaced by a specially designed curved mirror 11 in convex configuration which distorts the field of view giving a more even distribution over the ground plane of points relating to the centres of elements of a two-dimensional detector array (not shown). Figure 6 is a diagram corresponding to Figure 3, which illustrates that with the use of the mirror 11, the whole of the area between the walls can be viewed. The mirror itself is shown in perspective view in Figure 7. The table annexed to the end of this description defines the shape of the mirror in terms of x y and z coordinates, the individual figures giving the relative heights of points of the mirror from a ground plane. It will be noted that the mirror is symmetrical about the x=0 axis.

It is clear from a comparison of figures 3 and 6 that one effect of the mirror 11 is to spread the lines of points along the y axis for small values of y (short ranges) and bring closer together the lines of points for larger values of y (long ranges). In other words the images of far away objects are magnified more than those of close objects. To this end the mirror has along its x axis a concave portion for magnification and a convex portion to diminish the image as can be seen clearly in figure 7.

In a second example, the mirror illustrated in Figure 8 is used. This

mirror has a surface profile which is defined by the following formula, which defines the values of z for the various values of x and y indicated in the diagram, over the range $-48 \leq y \leq 8$ and $-11 \leq x \leq 11$, where all dimensions are in mm.

$$z = 7.5\text{x}10^{-3}x + 4\text{x}10^{-2}y + 8.75\text{x}10^{-4}xy^2 - 2.8\text{x}10^{-6}x^4 - 2.5\text{x}10^{-5}y^4 - 1.5\text{x}10^{-10}x^3y^4 + 1.4\text{x}10^{-11}x^4y^4$$

This mirror, 12, is designed to be mounted above a door 13 with a detector array 4, as shown in Figure 9, so that the door may be automatically opened on the approach of a person. The door is positioned in a straight section of a wall rather than at a corner. The mirror enables the array 4 to view the area of floor 14 in front of the door. Figure 10 is a plan view of the doorway and shows that the field of view 16 seen by the array must include the areas adjacent to the wall 15 in which the door is located. This is not possible with a conventional optical system mounted above the door. A comparison of figures 11 and 12 illustrates how the mirror 12 extends the normal field of view of the array to fully cover the region of ground approaching the door.

In other applications of distorted optics to detector arrays, the same principle may be applied to distort the field of view of a detector array so as to obtain a deliberately non-uniform distribution of pixels over the field of view.

The optical imaging system of this invention can be used in numerous applications including person or vehicle counters as well as detectors for intruder alarms and automatic door openers as described above.

y \ x (z)	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80
50	5.33	9.83	13.73	17.03	19.73	21.83	23.33	24.23	24.53	24.23	23.33	21.83	19.73	17.03	13.73	9.83	5.33
40	3.87	8.67	12.83	16.35	19.23	21.47	23.07	24.03	24.35	24.03	23.07	21.47	19.23	16.35	12.83	8.67	3.87
30	3.10	8.20	12.62	16.36	19.42	21.80	23.50	24.52	24.86	24.52	23.50	21.80	19.42	16.36	12.62	8.20	3.10
20	2.97	8.37	13.05	17.01	20.25	22.77	24.57	25.65	26.01	25.65	24.57	22.77	20.25	17.01	13.05	8.37	2.97
10	3.49	9.19	14.13	18.31	21.73	24.39	26.29	27.43	27.81	27.43	26.29	24.39	21.73	18.31	14.13	9.19	3.49
0	4.40	10.40	15.60	20.00	23.60	26.40	28.40	29.60	30.00	29.60	28.40	26.40	23.60	20.00	15.60	10.40	4.40
-10	6.74	12.74	17.94	22.34	25.94	28.74	30.74	31.94	32.34	31.94	30.74	28.74	25.94	22.34	17.94	12.74	6.74
-20	8.39	14.39	19.59	23.99	27.59	30.39	32.39	33.59	33.99	33.59	32.39	30.39	27.59	23.99	19.59	14.39	8.39
-30	9.18	15.18	20.38	24.78	28.38	31.18	33.18	34.38	34.78	34.38	33.18	31.18	28.38	24.78	20.38	15.18	9.18
-40	9.25	15.25	20.45	24.85	28.45	31.25	33.25	34.45	34.85	34.45	33.25	31.25	28.45	24.85	20.45	15.25	9.25
-50	8.87	14.87	20.07	24.47	28.07	30.87	32.87	34.07	34.47	34.07	32.87	30.87	28.07	24.47	20.07	14.87	8.87
-60	7.84	13.84	19.04	23.44	27.04	29.84	31.84	33.04	33.44	33.04	31.84	29.84	27.04	23.44	19.04	13.84	7.84
-70	6.17	12.17	17.37	21.77	25.37	28.17	30.17	31.37	31.77	31.37	30.17	28.17	25.37	21.77	17.37	12.17	6.17
-80	3.87	9.87	15.07	19.47	23.07	25.87	27.87	29.07	29.47	29.07	27.87	25.87	23.07	19.47	15.07	9.87	3.87
-90	0.92	6.92	12.12	16.52	20.12	22.92	24.92	26.12	26.52	26.12	24.92	22.92	20.12	16.52	12.12	6.92	0.92
-100	-2.67	3.33	8.53	12.93	16.53	19.33	21.33	22.53	22.93	22.53	21.33	19.33	16.53	12.93	8.53	3.33	-2.67
-110	-6.89	-0.89	4.31	8.71	12.31	15.11	17.11	18.31	18.71	18.31	17.11	15.11	12.31	8.71	4.31	-0.89	-6.89

Table 1 **Mirror surface coordinates**

Claims

1. An optical system for forming an image of a field of view in an object plane onto an image plane which is not parallel to the object plane in which a desired area of the object plane is mapped onto the image plane by means of a distorting optical element which imposes a non linear relationship between areas of the object plane and areas of the image plane.

2. An optical system as claimed in claim 1 in which one effect of the distorting optical element is to magnify the longitudinal field of view at short ranges.

3. An optical system as claimed in claim 2 in which the magnification increases with increasing range.

4. An optical system as claimed in claim 1,2 or 3 in which one effect of the distorting optical element is to compress the longitudinal field of view at short ranges.

5. An optical system in which the compression increases with decreasing range.

6. A system as claimed in any preceding claim in which the distorting optical element expands the lateral field of view.

7. A system as claimed in any preceding claim in which the distorting optical element is a reflective surface.

8. A system as claimed in any of claims 1 to 6 in which the distorting optical element is a refractive element.

9. A system as claimed in any preceding claim in which the distorting optical element causes a more uniform correspondence between areas of the object plane and areas of the image plane than would be present without the optical element.

10. A system as claimed in any preceding claim including an array of infrared detector elements at the image plane.

11. A system as claimed in any preceding claim including a lens for focussing the image onto the image plane.

12. A system as claimed in any preceding claim in which the object plane is an area of floor or ground and the image plane is at an acute angle to the object plane.

13. An optical system substantially as hereinbefore described with reference to figures 4 to 7 of the accompanying drawings.

14. An optical system substantially as hereinbefore described with reference to figures 8 to 10 of the accompanying drawings.

Abstract

Use of Distorted Optics in Imaging Systems

An optical imaging system for forming an image of a field of view in an object plane onto an image plane in which the electromagnetic radiation image is transmitted to the object plane via an optical distorting element such as a spherical reflector 11, preferably with a view to compensating for any foreshortening of the image caused by the inclination of the image plane to the object plane.

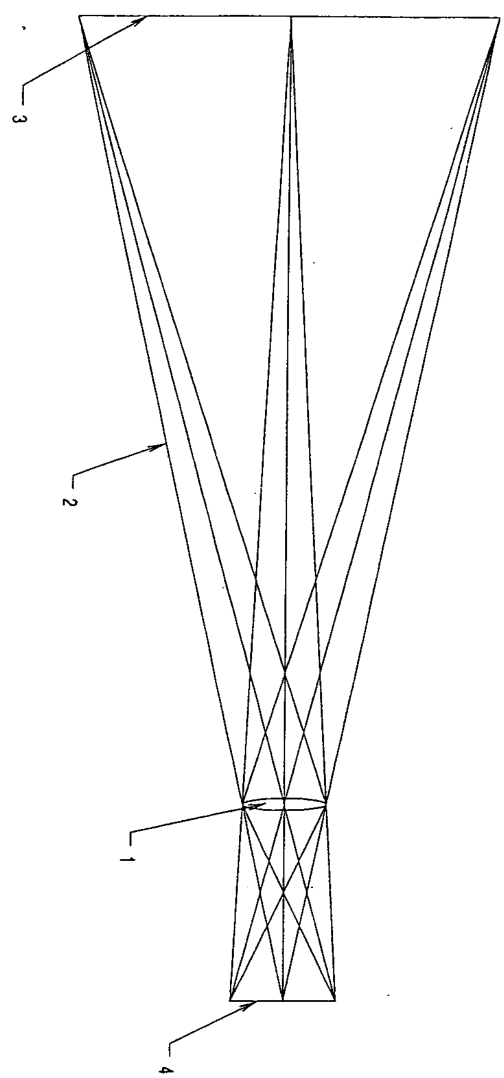

Figure 1

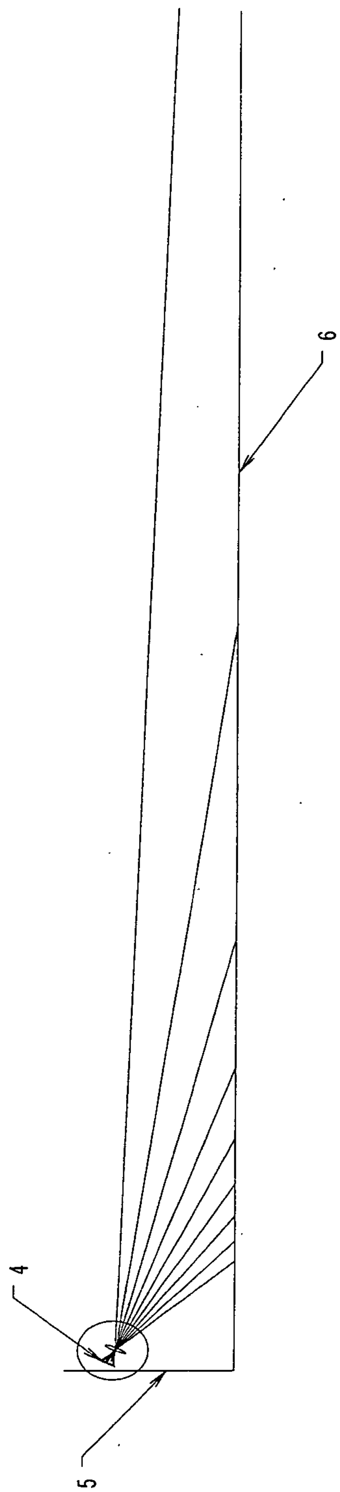

Figure 2

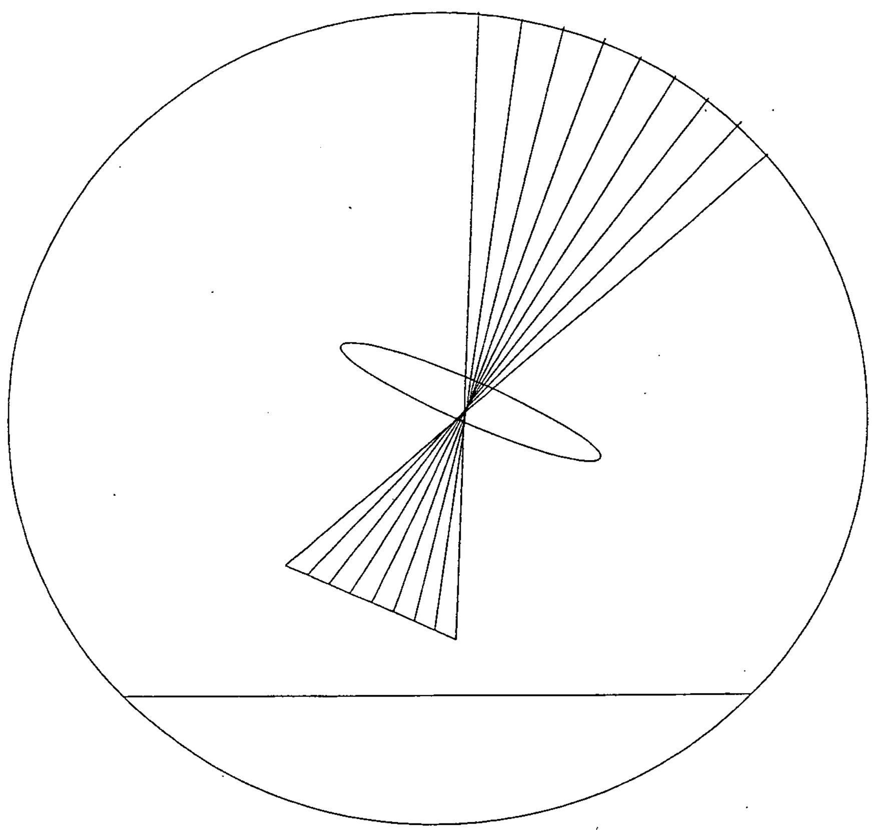

Figure 2A

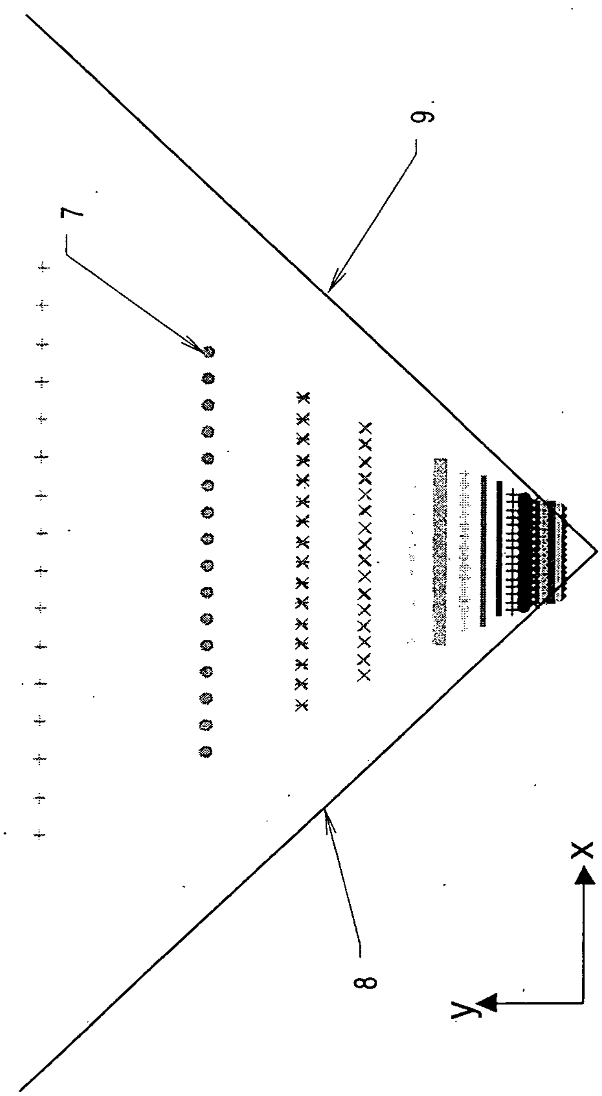

Figure 3

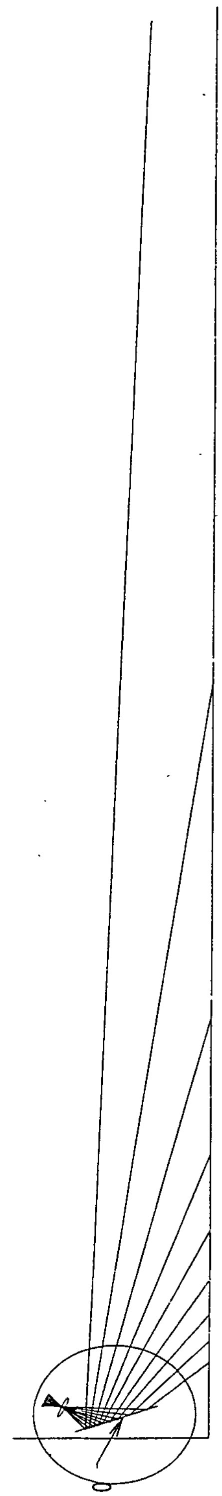

Figure 4

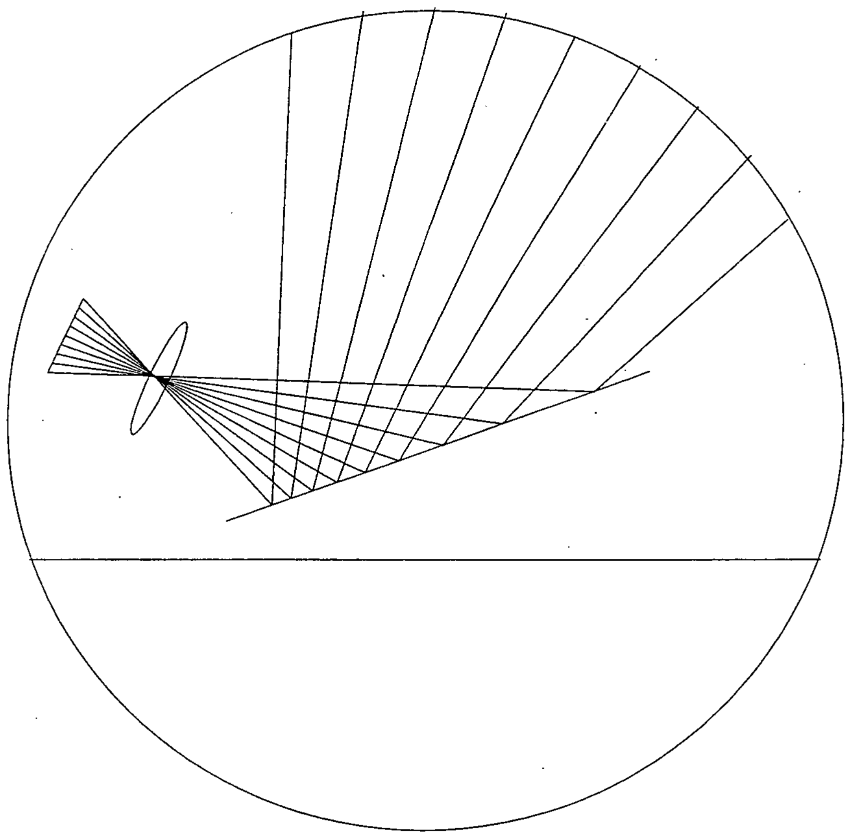

Figure 4A

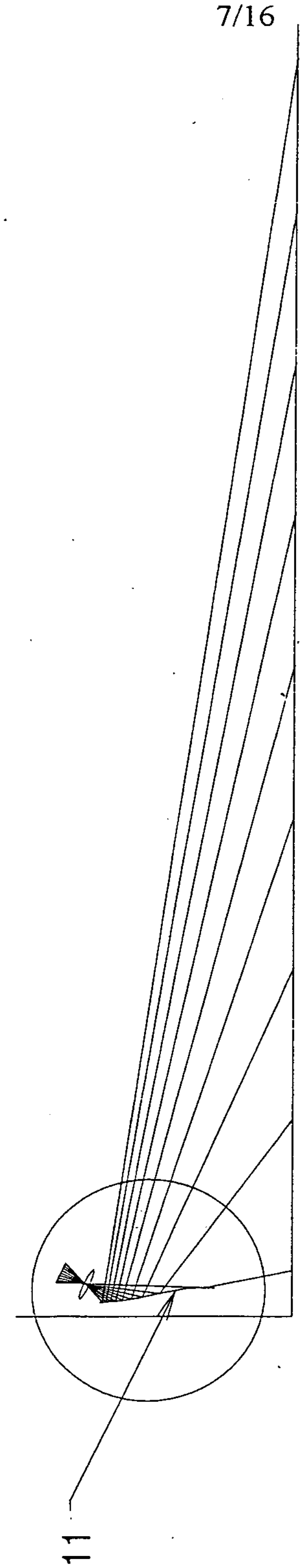

Figure 5

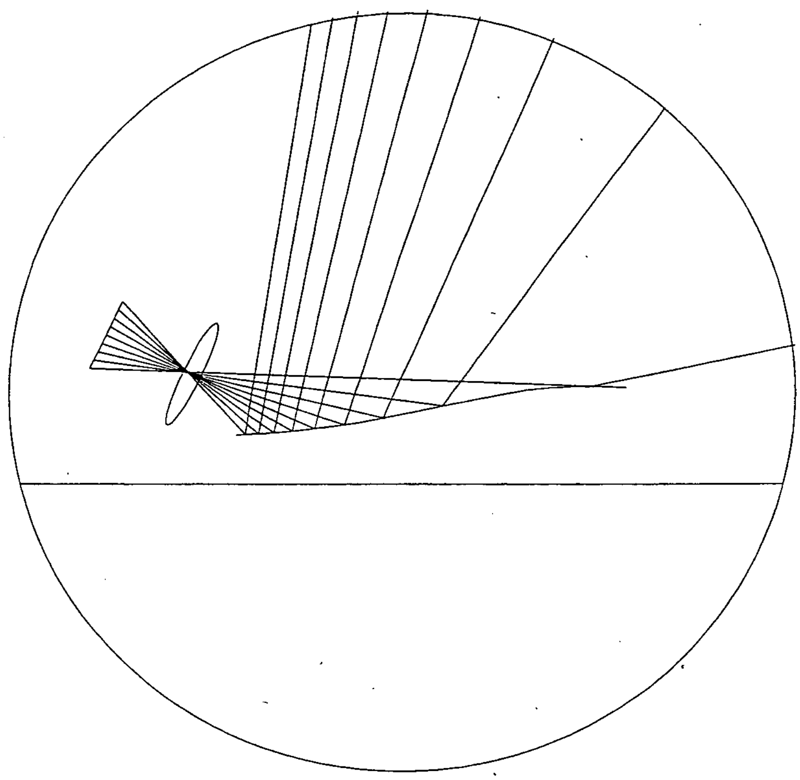

Figure 5A

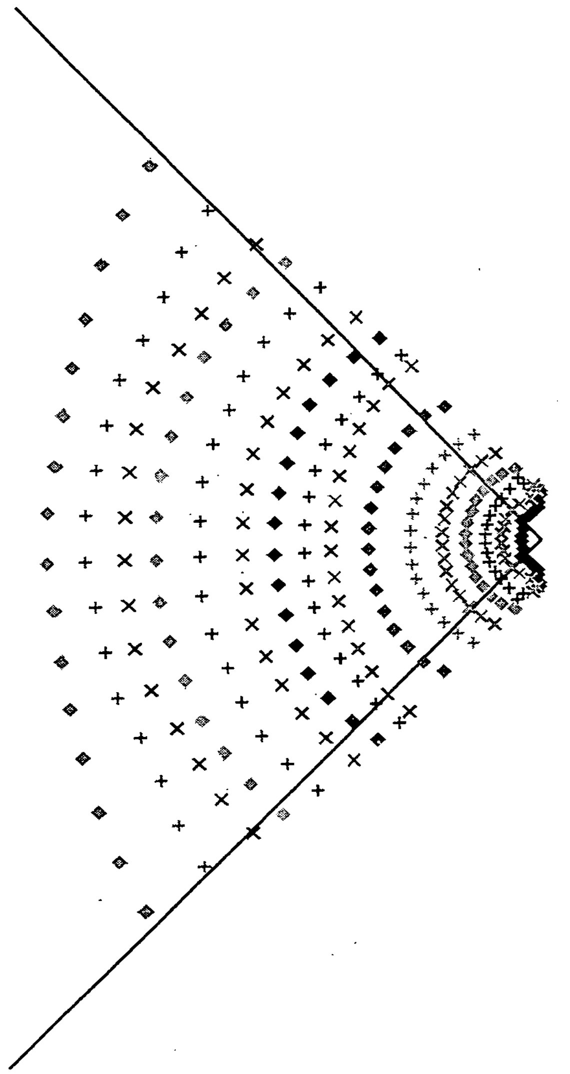

Figure 6

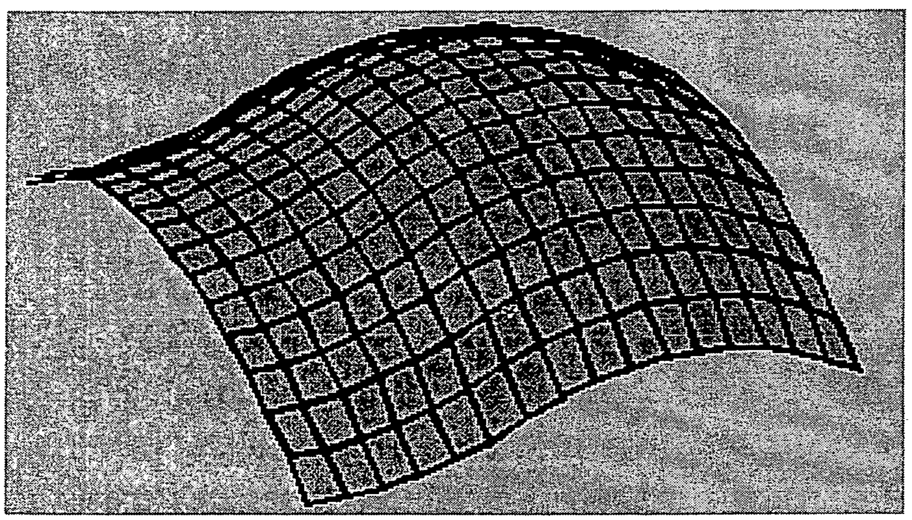

Figure 7

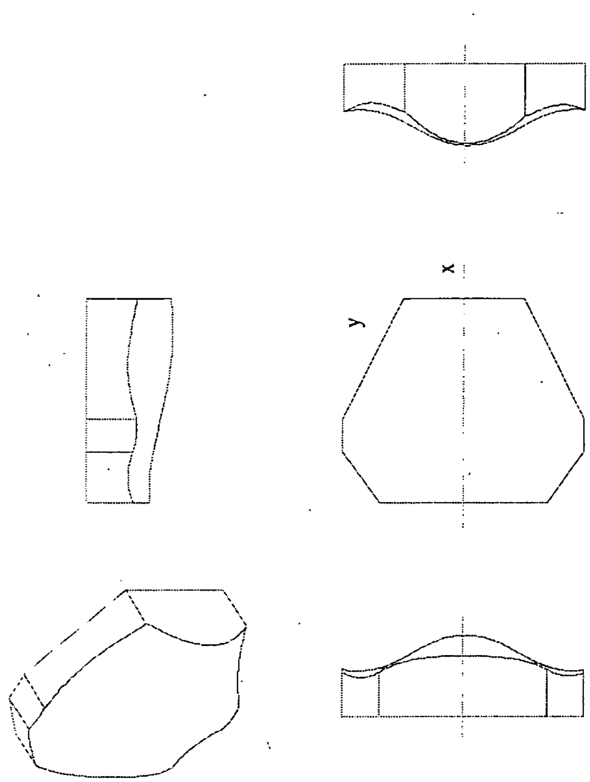

Figure 8

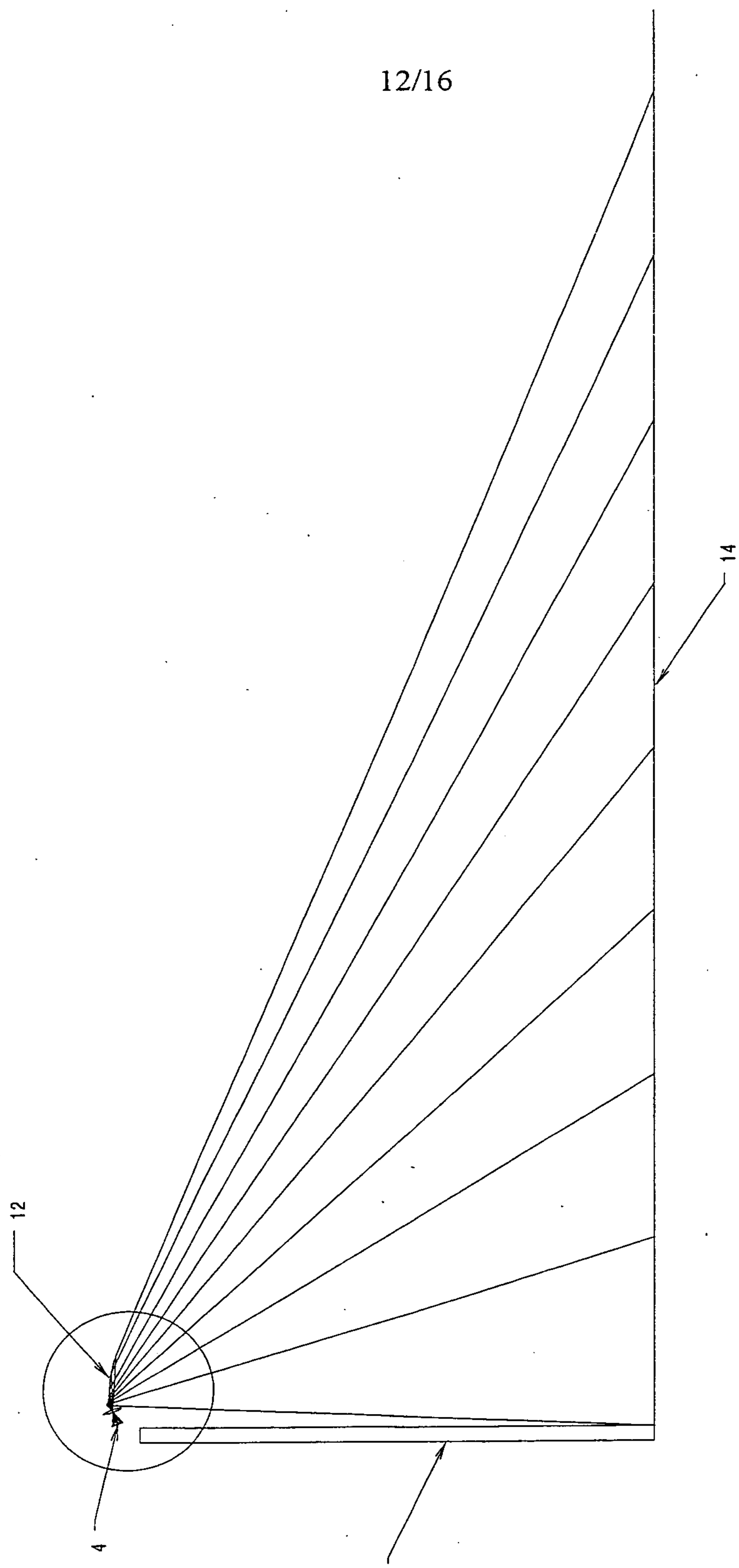

Figure 9

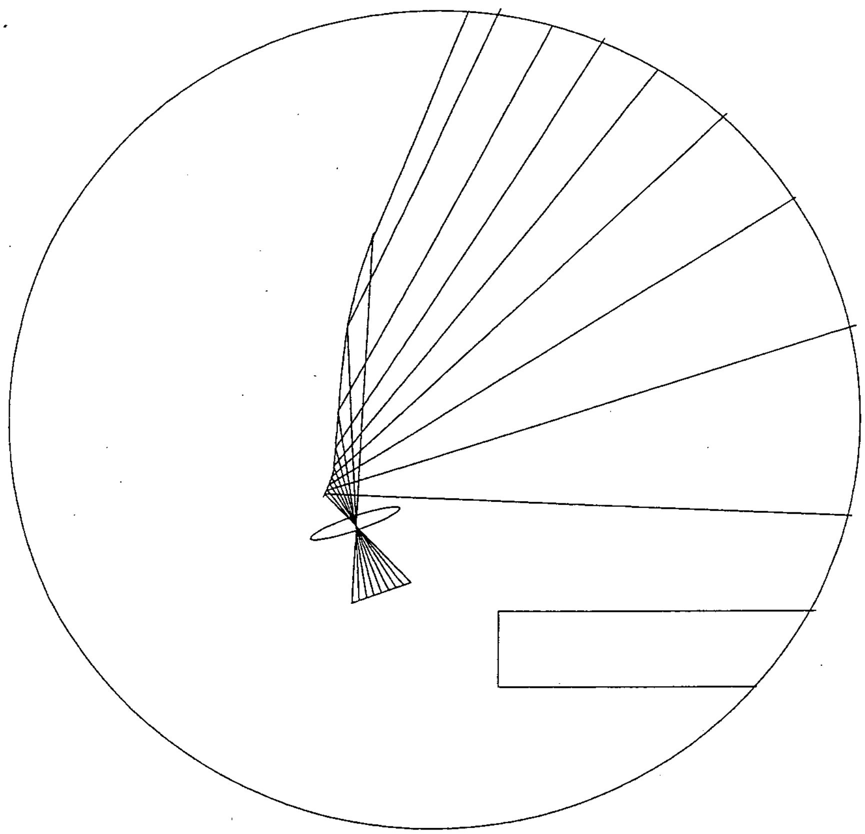

Figure 9A

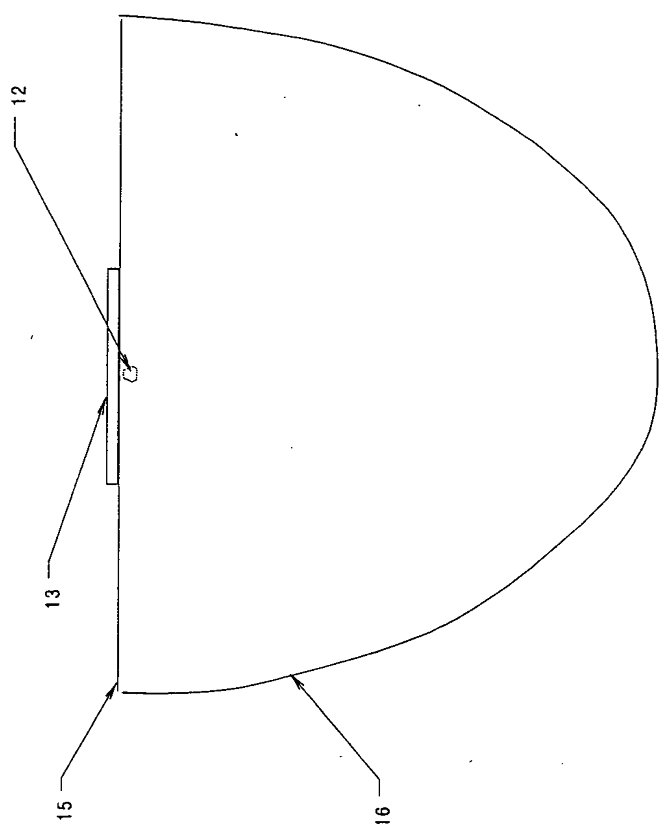

Figure 10

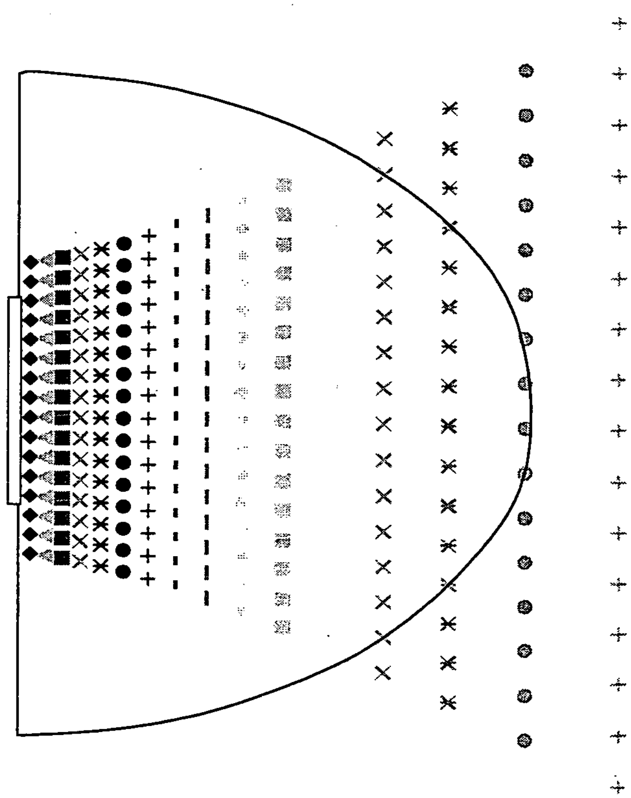

Figure 11

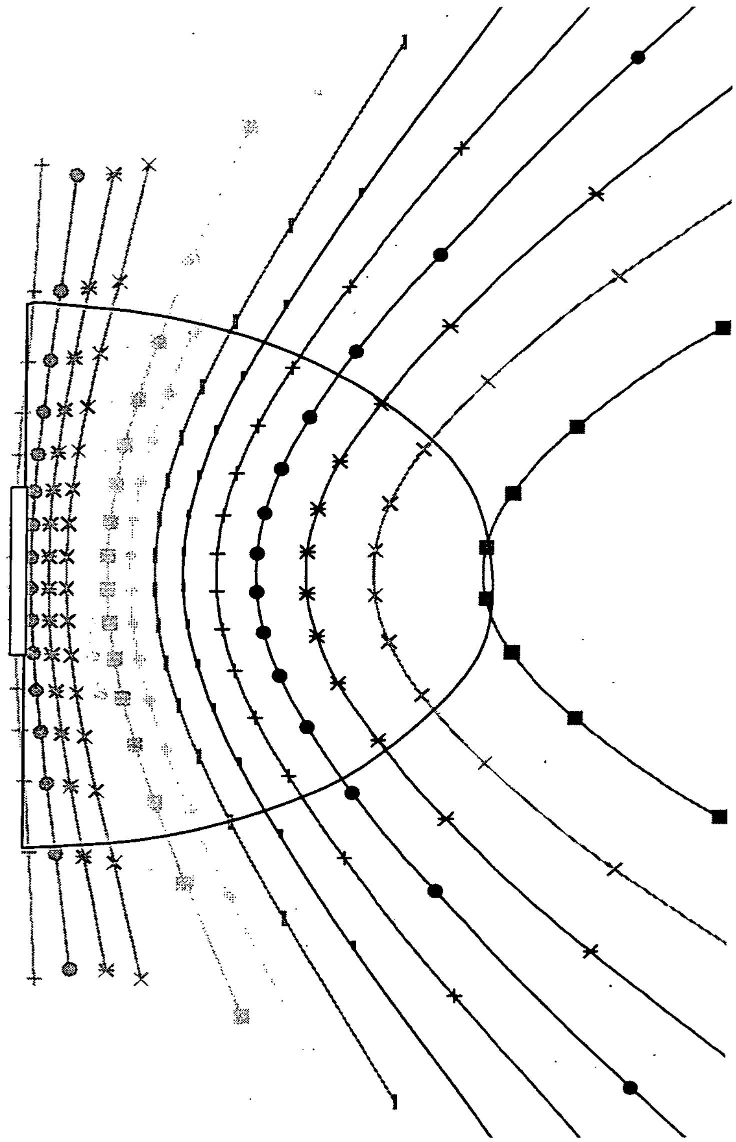

Figure 12